

# **Landsat Data Continuity Mission (LDCM) Data Specification**

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## **1.0 Introduction**

### **1.1 Background**

The Land Remote Sensing Policy Act of 1992 requires U.S. Government Landsat Program Management to “assess options for a successor land remote sensing system to Landsat 7.” The act further requires that the assessment of options consider the ability to “maintain data continuity with the Landsat system” and to “incorporate system enhancements ... which may potentially yield a system that is less expensive to build and operate, and more responsive to data users.” The data requirements listed herein derive from the following premise: The LDCM will be required to provide multispectral digital image data for global coverage of the Earth's land mass on a seasonal basis and in a manner that ensures continuity of the Landsat 7 mission.

### **1.2 Scope**

This document specifies the data and associated data services required from a successor system to Landsat 7 and includes all the verifiable requirements for these data and services. These requirements apply only to data purchased by the government through the LDCM program and to data products distributed to LDCM users. All references in this document to International Cooperators are to be adhered to only if applicable to the contractor's architecture and operational plans.

This specification does not explicitly allocate requirements between commercial or government entities, but rather is intended to leave the best value allocation to the eventual system provider.

### **1.3 Overview**

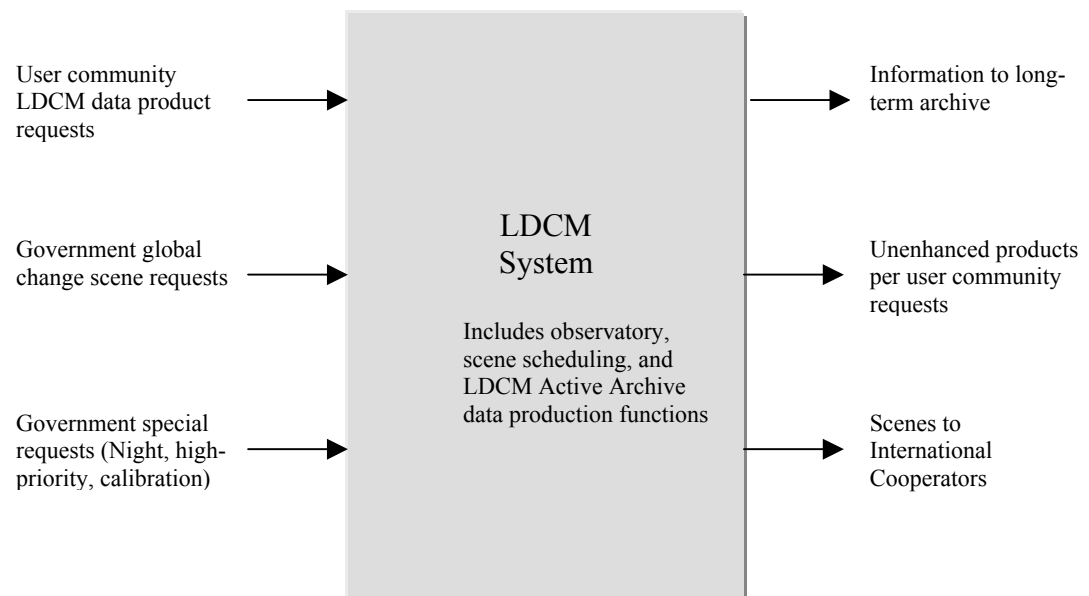
The LDCM performs the following basic functions:

- Acquisition of multispectral digital image data affording global coverage of the Earth's landmass on a seasonal basis. These data must be sufficiently consistent in terms of acquisition geometry, coverage characteristics, spectral characteristics, output product quality, and data availability to ensure continuity of the Landsat mission.
- Delivery of digital image data (and related descriptive data) to an active archive.
- Provision of search and order capabilities to governmental, scientific, and public users.
- Generation and distribution of unenhanced data products in response to user orders and in accordance with the LDCM Data Policy, Attachment D to the LDCM Request for Proposal (RFP).
- Delivery of LDCM data to International Cooperators (ICs).

- Transfer of LDCM data to a long-term archive.

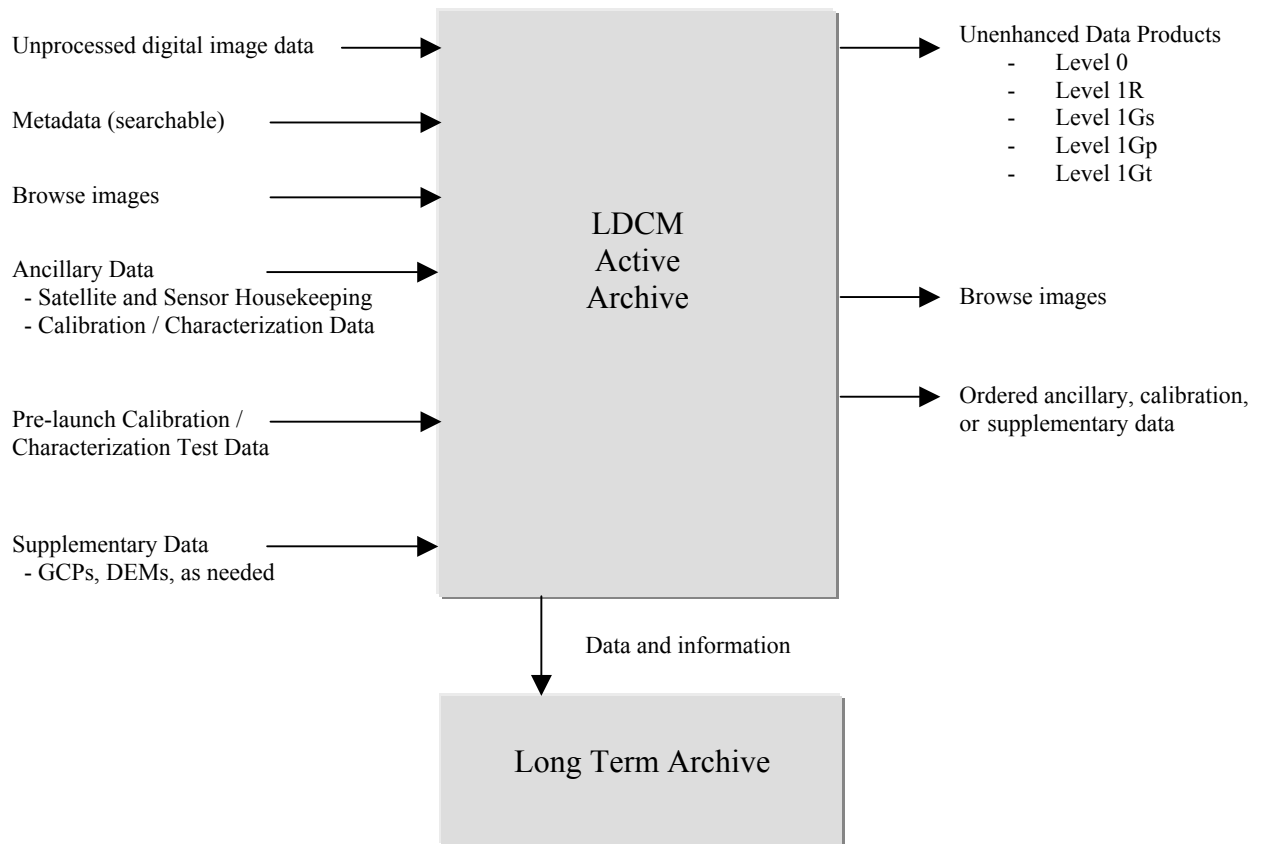
The high-level functionality of the LDCM is illustrated in Figure 1.3-1. The LDCM is driven by three major sets of inputs. The first set of inputs consists of data requests from the Landsat user community for data products based on archived data. The second set of inputs consists of government requests for global coverage scenes for the long-term archive. The third set of inputs is special requests including high priority, night images, or special calibration data products.

The LDCM also has three major sets of outputs. The first set of outputs consists of scenes provided to the long-term archive. The second set of outputs consists of unenhanced products provided per user community requests. The third set of outputs consists of scenes provided to International Cooperators.



**Figure 1.3-1 LDCM High Level Functionality**

From a data point of view, the LDCM archives data (as specified in Section 2.1 of this document) and produces and distributes data products (as specified in Section 2.2 of this document) in accordance with the LDCM Data Policy, Attachment D to the LDCM RFP. Figure 1.3-2 illustrates the data types that flow into and out of the LDCM active archive and the LDCM long-term archive. Note that all data products described in Section 2.2 are considered unenhanced data products in accordance with PL 102-555.



**Figure 1.3-2 LDCM Data Management Overview**

#### **1.4 Document Organization**

Section 2 specifies the data and data products archived, produced, and distributed by the LDCM. Section 3 defines the spatial coverage and temporal resolution, Section 4 delineates the required spectral characteristics, Section 5 describes the spatial resolution, and Section 6 characterizes the radiometry. Section 7 follows with the requirements for the geometry of LDCM data and Sections 8 and 9 identify optional thermal and reflective bands, respectively.

#### **1.5 Goal Identification**

On occasion, this document identifies goals beyond the specified requirements. These goals are shown in bold italics in the text. Table 1.5-1 references the location of all goal statements and summarizes their content.

**Table 1.5-1 Summary of Goals in LDCM Data Specification**

427-SPEC-00001 Reference #	Performance Specification	427-SPEC-00001 Requirement	Goal
Para. 2.2.4.c	Level 1Gp Products	U.S. Only	Global
Para. 2.2.5.c	Level 1Gt Products	U.S. Only	Global
Table 6.1-1	Saturation Radiance of SWIR 1	72.5	145
Table 6.1-1	Saturation Radiance of SWIR 2	24.7	49.4
Table 8.5.2.1-1	Saturation Temperature Bd. 10/11	340K	425K
Table 6.2.1-1, 8.5.2.1-2 & 9.5.2-1	SNR/NEDT	See requirements in referenced tables.	See goals (ALI values) in referenced tables.
Para. 7.1.1; Tables 8.6-1 & 9.6.1-1	Band-to-Band Registration for 1G Nearest Neighbor Products	15m Bands 1-8 60m Bands 9-11	3m Bands 1-8 12m Bands 9-11
Para. 7.1.2; Tables 8.6-2 & 9.6.2-1	Band-to-Band Registration for 1G Products	4.5m Bands 1-8 18m Bands 9-11	3m Bands 1-8 12m Bands 9-11
Para. 7.3.1	1Gs Absolute Geodetic Accuracy	65m 90% Cir. Error	50m 90% Cir. Error
Para. 6.1 & 9.5.1	Absolute Radiometric Accuracy Bands 1-9	5%	3%
Para. 8.5.1	Absolute Radiometric Accuracy Bands 10/11	2%	1%
Para. 8.5.2.3	Pixel-to-Pixel Uniformity (Thermal Band)	0.5%	0.25%

### **1.6 Applicable Documents and Information**

a) Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (revised June 1998), FGDC-STD-001-1998. Federal Geographic Data Committee, Washington DC (<http://www.fgdc.gov/metadata/csdgm/>)

b) Top of Atmosphere Radiance Values, MODTRAN 4 Model (see Bidders' Library: <http://www.ldcm.nasa.gov>)



c) World Geodetic System 1984 (WGS84), National Imagery and Mapping Agency, Department of Defense World Geodetic System 1984: Its Definition and Relationships with Local Geodetic Systems, Technical Report 8350.2, Third Edition, January 2000. (<http://www.wgs84.com/wgs84/downloads.htm>)

d) Landsat 7 Worldwide Reference System-2 (WRS-2): U.S. Geological Survey EROS Data Center, Landsat 7 Image Assessment System (IAS) Geometric Algorithm Theoretical Basis Document, Version 3.2, Sioux Falls, South Dakota, July 1998, pp. 74-76

e) Worldwide Reference System Land Database, revision 2.1 (<http://landsat7.usgs.gov/acqplan.html>)

## **2.0 LDCM Data and Data Products**

The LDCM shall deliver the following LDCM data and data products for a period of five years beginning at Initial Operational Capability (IOC). The specifications given herein shall apply for the life of the LDCM. The LDCM shall archive the data specified in Section 2.1 and shall produce and distribute the data products specified in Section 2.2 in accordance with the LDCM Data Policy, Attachment D to the LDCM RFP.

The LDCM shall operationally deliver calibrated, validated, on-orbit data and products no later than March 2006 as stated herein.

Please refer to Figure 1.3-2 for an overview of LDCM data types and data flows.

The facility that archives the data specified in Section 2.1 and that produces and distributes the data products specified in Section 2.2 is herein referred to as the LDCM Active Archive. The USGS EROS Data Center serves as the Government's Long Term Archive.

### **2.1 Archived LDCM Data**

The LDCM shall archive unprocessed LDCM digital image data, metadata, browse images, and associated ancillary data.

- 2.1.a** The unprocessed LDCM digital image data and ancillary data shall include all information necessary to generate the LDCM data products specified in Section 2.2.
- 2.1.b** The unprocessed LDCM digital image data and ancillary data shall be of a quality and quantity necessary to ensure that the LDCM data products meet the data specifications found in Sections 3, 4, 5, 6, and 7.
- 2.1.c** The archived LDCM digital image data shall afford at a minimum the geographic coverage and temporal resolution specified in Section 3.

#### **2.1.1 Unprocessed LDCM Digital Image Data**

Unprocessed LDCM digital image data are those digital image data directly generated by the LDCM sensor(s) and transmitted from the LDCM satellite(s). The numerical value of the digital image data from sensor to archive shall be preserved.

##### **2.1.1.1 Unprocessed LDCM Digital Image Data Lossless Compression**

Unprocessed LDCM digital image data, after any compression and decompression, shall be identical to the data prior to compression.

### **2.1.1.2 Unprocessed LDCM Digital Image Data Quality**

#### **2.1.1.2.1 Dead or Inoperable Detectors**

Less than 0.1% of the unprocessed LDCM digital image data archived daily shall be produced by dead or inoperable detectors.

#### **2.1.1.2.2 Transmission Errors**

The bit error rate resulting from the transmission (from observatory to archive) of unprocessed LDCM digital image data shall be no greater than 1 bit in  $10^8$  bits.

#### **2.1.1.2.3 Archive Errors**

The LDCM ground data processing and archival shall introduce no more than one bit error in  $10^{12}$  bits processed and archived.

### **2.1.2 Ancillary Data**

The LDCM shall archive ancillary data associated with the archived unprocessed LDCM digital image data. The ancillary data shall consist of:

- 2.1.2.a** satellite and sensor housekeeping data required to generate the specified data products
- 2.1.2.b** calibration data required to generate the specified data products
- 2.1.2.c** any other supplementary data required to generate the specified data products.

#### **2.1.2.1 Sensor and Satellite Housekeeping Data**

The archived housekeeping data shall:

- 2.1.2.1.a** quantify the state of the LDCM sensor and satellite systems during acquisition of the unprocessed LDCM digital image data
- 2.1.2.1.b** at a minimum provide the sensor/satellite state information required to generate the specified LDCM data products
- 2.1.2.1.c** at a minimum provide the sensor/satellite state information required to verify the performance of the LDCM sensor(s) and satellite(s)
- 2.1.2.1.d** either be in metric engineering units or the archive shall provide the conversion factors required to convert the housekeeping data to metric engineering units.

#### **2.1.2.2 Pre-Launch Characterization and Calibration Data**

The LDCM shall archive all pre-launch test data acquired for the purpose of characterizing and calibrating the performance of the LDCM sensor(s), including the radiometric response and the image geometry.

#### **2.1.2.3 On-Orbit Characterization and Calibration Data**

- 2.1.2.3.a** The LDCM shall archive all data acquired in orbit for the purpose of characterizing and calibrating the performance of the LDCM sensor(s), including those data acquired to characterize and calibrate radiometric response and image geometry.
- 2.1.2.3.b** The calibration data shall include, but not be limited to, data acquired while viewing radiometric reference sources or geometric targets.
- 2.1.2.3.c** The archived calibration data shall also include all of the derived calibration coefficients required to generate the specified LDCM data products including radiometric gains and biases and detector, sensor, and satellite alignment parameters.

#### **2.1.2.4 Supplementary Data**

The LDCM shall archive all of the supplementary data required to generate the data products described in Section 2.2.

### **2.1.3 Metadata**

- 2.1.3.a** The LDCM shall archive metadata for each granule of archived, unprocessed LDCM digital image data.
- 2.1.3.b** The metadata shall adhere to the Federal Geographic Data Committee (FGDC) standards for metadata.
- 2.1.3.c** The metadata shall include but not be limited to:
  - 2.1.3.c.1** The WRS-2 path and row for each WRS-2 scene within an archived digital image granule
  - 2.1.3.c.2** The acquisition date for the archived digital image data granule
  - 2.1.3.c.3** The acquisition start time and end time for the archived digital image granule and the acquisition start time and

end time for each of the WRS-2 scenes within the granule

- 2.1.3.c.4** Solar azimuth and zenith angles (in degrees, accurate to 3 decimal places) at the center of each WRS-2 scene within an archived digital image granule at the date and time of data acquisition
- 2.1.3.c.5** Identification of the satellite and sensor that acquired the digital image data
- 2.1.3.c.6** Identification of the ground station that initially received the digital image data granule
- 2.1.3.c.7** Identification of the data's path to the LDCM archive
- 2.1.3.c.8** The spectral bands provided by the digital image data
- 2.1.3.c.9** The geographic location of the corner points of the archived digital image data granule with an uncertainty of less than or equal to 250 meters (90% circular error), excluding terrain effects
- 2.1.3.c.10** The geographic location of the corner points of each WRS-2 scene within an archived digital image data granule with an uncertainty of less than or equal to 250 meters (90% circular error), excluding terrain effects
- 2.1.3.c.11** The geographic location of the center of each WRS-2 scene within an archived digital image data granule with an uncertainty of less than or equal to 250 meters (90% circular error), excluding terrain effects
- 2.1.3.c.12** The percentage cloud cover for each WRS-2 scene within an archived digital image data granule with an uncertainty of plus or minus 10%, 95% of the time
- 2.1.3.c.13** The percentage cloud cover for each of the four quadrants of each WRS-2 scene within a digital image data granule with an uncertainty of plus or minus 10%, 95% of the time
- 2.1.3.c.14** Data quality metrics for each WRS-2 scene within a digital image data granule

- 2.1.3.c.15** Locations of corrupted or invalid data within the digital image data granule
- 2.1.3.c.16** Descriptions or characterizations of the corrupted or invalid data
- 2.1.3.c.17** The sensor settings for variable sensor states at the time of data acquisition
- 2.1.3.c.18** The date of data archival
- 2.1.3.c.19** Identification of the facility, computer system, and software versions used to process and archive the digital image data.

#### **2.1.4 Browse Images**

The LDCM shall generate and archive browse images for the archived, unprocessed LDCM digital image data.

- 2.1.4.a** Browse Images shall be generated for each WRS-2 scene contained within the archived digital image data.
- 2.1.4.b** The browse images shall provide a spatial resolution no coarser than 240 m.
- 2.1.4.c** The browse images shall be composites of at least three bands that enable differentiation of clouds from land with at least 8 bits per display channel.

#### **2.2 LDCM Data Products**

For any of the data in the LDCM Active Archive, except where noted, the LDCM shall produce and distribute the following LDCM data products in accordance with the LDCM Data Policy, Attachment D to the LDCM RFP.

##### **2.2.1 Level 0 LDCM Data Products**

Level 0 LDCM Data Products shall consist of Level 0 Digital Image Data, Level 0 Ancillary Data, and Level 0 Metadata.

- 2.2.1.a** The Level 0 LDCM Data Product shall provide all of the data required to produce the data products specified in Sections 2.2.2 and 2.2.3.
- 2.2.1.b** The LDCM shall produce and distribute Level 0 LDCM Data Products for the data granules specified in Section 2.4 and in the formats specified in Section 2.5.

- 2.2.1.c** The LDCM shall produce Level 0 LDCM Data Products for any of the unprocessed LDCM digital image data in the LDCM Active Archive.

**2.2.1.1 LDCM Level 0 Digital Image Data**

Level 0 Digital Image Data shall consist of unprocessed LDCM digital image data produced in the

- 2.2.1.1.a** data granules specified in Section 2.4

- 2.2.1.1.b** formats specified in Section 2.5

**2.2.1.2 LDCM Level 0 Ancillary Data**

- 2.2.1.2.a** Level 0 Ancillary Data shall provide all of the ancillary data required to generate the products specified in Sections 2.2.2 and 2.2.3.

- 2.2.1.2.b** The Level 0 Ancillary Data shall include, but not be limited to, the calibration coefficients and housekeeping data required to create Level 1 products, in metric engineering units.

**2.2.1.3 LDCM Level 0 Metadata**

- 2.2.1.3.a** Level 0 Metadata shall describe the associated Level 0 Digital Image Data and Level 0 Ancillary Data.

- 2.2.1.3.b** Level 0 Metadata shall adhere to the Federal Geographic Data Committee (FGDC) standards for metadata.

- 2.2.1.3.c** Level 0 Metadata shall include, but not be limited to:

- 2.2.1.3.c.1** The WRS-2 path and row for each WRS-2 scene within a data product

- 2.2.1.3.c.2** The acquisition date for the data product

- 2.2.1.3.c.3** The acquisition start time and end time for the data product and the acquisition start time and end time for each of the WRS-2 scenes within the data product

- 2.2.1.3.c.4** Solar azimuth and zenith angles (in degrees, accurate to 3 decimal places) at the center

of each WRS-2 scene within the data product at the date and time of data acquisition

- 2.2.1.3.c.5** Identification of the satellite and sensor that acquired the digital image data
- 2.2.1.3.c.6** Identification of the ground station that initially received the digital image data
- 2.2.1.3.c.7** Identification of the data's path to the LDCM archive
- 2.2.1.3.c.8** The spectral bands provided by the digital image data
- 2.2.1.3.c.9** The geographic location of the corner points of the data product with an uncertainty of less than or equal to 250 meters (90% circular error), excluding terrain effects
- 2.2.1.3.c.10** The geographic location of the corner points of each WRS-2 scene within the data product with an uncertainty of less than or equal to 250 meters (90% circular error), excluding terrain effects
- 2.2.1.3.c.11** The geographic location of the center of each WRS-2 scene within the data product with an uncertainty of less than or equal to 250 meters (90% circular error), excluding terrain effects
- 2.2.1.3.c.12** The percentage cloud cover for each WRS-2 scene the data product with an uncertainty of plus or minus 10%, 95% of the time
- 2.2.1.3.c.13** The percentage cloud cover for each of the four quadrants of each WRS-2 scene within the data product with an uncertainty of plus or minus 10%, 95% of the time
- 2.2.1.3.c.14** Data quality metrics for each WRS-2 scene within the data product



- 2.2.1.3.c.15** Locations of corrupted or invalid data within the data product
- 2.2.1.3.c.16** Descriptions or characterizations of the corrupted or invalid data
- 2.2.1.3.c.17** The sensor settings for variable sensor states at the time of data acquisition
- 2.2.1.3.c.18** The date of data archival
- 2.2.1.3.c.19** Identification of the facility, computer system, software, and software versions that generated the data product.
- 2.2.1.3.c.20** Date of product generation.

## **2.2.2 Level 1R LDCM Data Products**

Level 1R LDCM Data Products shall consist of Level 1R Digital Image Data, Level 1R Ancillary Data, and Level 1R Metadata.

- 2.2.2.a** The LDCM shall produce and distribute Level 1R LDCM Data Products for the data granules specified in Section 2.4 and in the formats specified in Section 2.5.
- 2.2.2.b** The LDCM shall produce Level 1R LDCM Data Products for any of the unprocessed LDCM digital image data in the LDCM archive.

### **2.2.2.1 Level 1R Digital Image Data**

- 2.2.2.1.a** Level 1R Digital Image Data shall provide radiometrically corrected digital image data consisting of digital values linearly scaled to at-aperture spectral radiance.
- 2.2.2.1.b** The linear scale shall be constant for all the data from a particular spectral band.

### **2.2.2.2 Level 1R Ancillary Data**

The Level 1R Ancillary Data shall be identical in content to the Level 0 Ancillary Data for the corresponding Level 0 data product.

### **2.2.2.3 Level 1R Metadata**

**2.2.2.3.a** Level 1R Metadata shall describe the associated Level 1R Digital Image Data and Level 1R Ancillary Data.

**2.2.2.3.b** Level 1R Metadata shall adhere to the Federal Geographic Data Committee (FGDC) standards for metadata.

**2.2.2.3.c** Level 1R Metadata shall include, but not be limited to:

**2.2.2.3.c.1** all of the items listed in Section 2.2.1.3

**2.2.2.3.c.2** The version of the calibration coefficients used to generate the Level 1R Digital Image Data

**2.2.2.3.c.3** The radiometric coefficients required to convert the digital values of the Level 1R digital image data to units of spectral radiance with the accuracy specified in Section 6.1.

### **2.2.3 Level 1Gs LDCM Data Products**

Level 1Gs LDCM Data Products shall consist of Level 1Gs Digital Image Data and Level 1Gs Metadata.

**2.2.3.a** The LDCM shall produce and distribute Level 1Gs LDCM Data Products for the data granules specified in Section 2.4 and in the formats specified in Section 2.5.

**2.2.3.b** The LDCM shall produce Level 1Gs LDCM Data Products for any of the unprocessed LDCM digital image data in the LDCM archive.

#### **2.2.3.1 Level 1Gs Digital Image Data**

**2.2.3.1.a** Level 1Gs Digital Image Data shall consist of radiometrically corrected digital image data resampled for registration to selectable cartographic projections, as specified in Section 2.3, referenced to the World Geodetic System 1984 (WGS84), G873 or current version.

**2.2.3.1.b** Image resampling shall be performed using selectable resampling methods, as specified in Section 2.3.2.

**2.2.3.1.c** The pixels of the Level 1Gs Digital Image Data shall be registered to the geodetic accuracy specified in Section 7.3.

**2.2.3.1.d** The digital values shall be linearly scaled to at-aperture spectral radiance.

**2.2.3.2 Level 1Gs Metadata**

Level 1Gs Metadata shall describe the associated Level 1Gs Digital Image Data.

**2.2.3.2.a** Level 1Gs Metadata shall adhere to the Federal Geographic Data Committee (FGDC) standards for metadata.

**2.2.3.2.b** Level 1Gs Metadata shall include, but not be limited to:

**2.2.3.2.b.1** all of the items listed in Section 2.2.1.3

**2.2.3.2.b.2** The version of the calibration coefficients used to generate the Level 1Gs Digital Image Data

**2.2.3.2.b.3** The radiometric coefficients required to convert the digital values of the Level 1Gs digital image data to units of spectral radiance with the accuracy specified in Section 6.1

**2.2.3.2.b.4** The cartographic projection

**2.2.3.2.b.5** The cartographic projection parameters

**2.2.3.2.b.6** The current version of the WGS84 ordinate reference frame

**2.2.3.2.b.7** Identification of any supplementary data used to generate the Level 1Gs Digital Image Data

**2.2.3.2.b.8** Product corner points with the accuracy specified in Section 7.3

**2.2.3.2.b.9** User-selected processing parameters for the data products ordered.

### **2.2.4 Level 1Gp LDCM Data Products**

Level 1Gp LDCM Data Products shall consist of Level 1Gp Digital Image Data and Level 1Gp Metadata.

- 2.2.4.a** The LDCM shall produce and distribute Level 1Gp LDCM Data Products for the data granules specified in Section 2.4 and in the formats specified in Section 2.5.
- 2.2.4.b** The LDCM shall produce Level 1Gp LDCM Data Products for any of the daylight, archived, unprocessed LDCM digital image data acquired over the fifty United States and the District of Columbia.
- 2.2.4.c** *The LDCM will have the goal of producing Level 1Gp LDCM Data Products for any of the daylight, land LDCM digital image data in the LDCM archive.*

#### **2.2.4.1 Level 1Gp Digital Image Data**

- 2.2.4.1.a** Level 1Gp Digital Image Data shall consist of radiometrically corrected digital image data resampled for registration to selectable cartographic projections, as specified in Section 2.3, referenced to the World Geodetic System 1984 (WGS84), G873 or current version.
- 2.2.4.1.b** Image resampling shall be performed using selectable resampling methods, as specified in Section 2.3.2.
- 2.2.4.1.c** The pixels of the Level 1Gp Digital Image Data shall be registered to the geodetic accuracy specified in Section 7.4.
- 2.2.4.1.d** The digital values shall be linearly scaled to at-aperture spectral radiance.

#### **2.2.4.2 Level 1Gp Metadata**

Level 1Gp Metadata shall describe the associated Level 1Gp Digital Image Data.

- 2.2.4.2.a** Level 1Gp Metadata shall adhere to the Federal Geographic Data Committee (FGDC) standards for metadata.

**2.2.4.2.b** Level 1Gp Metadata shall include, but not be limited to:

**2.2.4.2.b.1** all of the items listed in Section 2.2.1.3.

**2.2.4.2.b.2** The version of the calibration coefficients used to generate the Level 1Gp Digital Image Data

**2.2.4.2.b.3** The radiometric coefficients required to convert the digital values of the Level 1Gp digital image data to units of spectral radiance with the accuracy specified in section 6.1

**2.2.4.2.b.4** The cartographic projection

**2.2.4.2.b.5** The cartographic projection parameters

**2.2.4.2.b.6** The current version of the WGS84 ordinate reference frame

**2.2.4.2.b.7** Identification of any supplementary data used to generate the Level 1Gp Digital Image Data.

**2.2.4.2.b.8** Product corner points with the accuracy specified in Section 7.4.

**2.2.4.2.b.9** User-selected processing parameters for the data products ordered.

**2.2.5 Level 1Gt LDCM Data Products**

Level 1Gt LDCM Data Products shall consist of Level 1Gt Digital Image Data and Level 1Gt Metadata. The LDCM shall

**2.2.5.a** produce and distribute Level 1Gt LDCM Data Products for the data granules specified in Section 2.4 and in the formats specified in Section 2.5.

**2.2.5.b** produce Level 1Gt LDCM Data Products for any of the daylight, archived, unprocessed LDCM digital image data acquired over the fifty United States and the District of Columbia

**2.2.5.c** *have the goal of producing Level 1Gt LDCM Data Products for any of the daylight, land LDCM digital image data in the LDCM archive.*

### **2.2.5.1 Level 1Gt Digital Image Data**

- 2.2.5.1.a** Level 1Gt Digital Image Data shall consist of radiometrically corrected digital image data resampled for orthorectification and registration to selectable cartographic projections, as specified in Section 2.3, referenced to the World Geodetic System 1984 (WGS84), G873 or current version.
- 2.2.5.1.b** Image resampling shall be performed using selectable resampling methods, as specified in Section 2.3.2.
- 2.2.5.1.c** The pixels of the Level 1Gt Digital Image Data shall be registered to the geodetic accuracy specified in Section 7.5.
- 2.2.5.1.d** The digital values shall be linearly scaled to at-aperture spectral radiance.

### **2.2.5.2 Level 1Gt Metadata**

Level 1Gt Metadata shall describe the associated Level 1Gt Digital Image Data.

- 2.2.5.2.a** Level 1Gt Metadata shall adhere to the Federal Geographic Data Committee (FGDC) standards for metadata.
- 2.2.5.2.b** Level 1Gt Metadata shall include, but not be limited to:
  - 2.2.5.2.b.1** all of the items listed in Section 2.2.1.3.
  - 2.2.5.2.b.2** The version of the calibration coefficients used to generate the Level 1Gt Digital Image Data
  - 2.2.5.2.b.3** The radiometric coefficients require to convert the digital values of the Level 1Gt digital image data to units of spectral radiance with the accuracy specified in Section 6.1
  - 2.2.5.2.b.4** The cartographic projection
  - 2.2.5.2.b.5** The cartographic projection parameters

**2.2.5.2.b.6** The current version of the WGS84 ordinate reference frame

**2.2.5.2.b.7** Identification of any supplementary data used to generate the Level 1Gt Digital Image Data

**2.2.5.2.b.8** Product corner points with the accuracy specified in Section 7.5.

**2.2.5.2.b.9** User-selected processing parameters for the data products ordered.

### **2.3 Cartographic Registration**

The Level 1Gs, Level 1Gp, and Level 1Gt LDCM Digital Image Data produced and distributed by the LDCM shall be registered to selectable cartographic projections by resampling the image data onto a regular grid in the projection space, with the output image grid aligned per user request to:

**2.3.a** Map projection grid north, or

**2.3.b** The nominal WRS-2 ground track

#### **2.3.1 Cartographic Projections**

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt products shall be registered to selectable cartographic projections including, but not limited to:

**2.3.1.a** Universal Transverse Mercator

**2.3.1.b** Lambert Conformal Conic

**2.3.1.c** Polar Stereographic

**2.3.1.d** Polyconic

**2.3.1.e** Transverse Mercator

**2.3.1.f** Oblique Mercator

**2.3.1.g** Space Oblique Mercator

**2.3.1.h** NAD83 State Plane

**2.3.1.i** Albers Equal Area

**2.3.1.j** Interrupted Goode Homolosine

**2.3.1.k** Mercator

**2.3.1.l** Equidistant Conic

**2.3.2 Resampling Methods**

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt products shall be resampled into a selected cartographic projection system using customer-selectable resampling methods including:

**2.3.2.a** nearest neighbor

**2.3.2.b** bilinear interpolation

**2.3.2.c** cubic convolution interpolation

**2.3.2.d** modulation transfer function compensation interpolation.

**2.3.3 Resampled Grid Cell Size Characteristics**

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt products shall be resampled into a selected cartographic projection system using customer-specified grid cell (i.e., resampled output pixel) sizes, with the characteristics defined in the following subsections.

**2.3.3.1 Selectable Resampled Grid Cell Sizes**

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product grid cell sizes shall be independently selectable for the following band groups:

**2.3.3.1.a** standard reflective bands (bands 2 through 7)

**2.3.3.1.b** sharpening band (band 8).

**2.3.3.2 Resampled Grid Cell Size Ranges**

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product grid cell sizes shall be selectable with the minimum ranges specified in Table 2.3.3.2-1.

Note: product throughput will be based upon the nominal grid cell sizes in Table 2.3.3.2-1.



**Table 2.3.3.2-1: Resampled Grid Cell Sizes**

<b>Band Group</b>	<b>Standard Reflective Bands</b>	<b>Sharpening Band</b>
Size Range	15 m - 60 m	10 m - 60 m
Nominal Size	30 m	15 m

**2.3.3.3 Resampled Grid Cell Size Increment**

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product grid cell sizes shall be selectable in increments of 0.001 meters or smaller.

**2.4 LDCM Data Product Granules**

**2.4.1 WRS-2 Scenes**

The LDCM shall be capable of producing and distributing Level 0, Level 1R, Level 1Gs, 1Gp, and Level 1Gt Data Products corresponding to the heritage Worldwide Reference System-2 (WRS-2) path/row scenes (185 x 180 km).

**2.4.2 Sub-Scenes**

- 2.4.2.a** The LDCM shall produce and distribute at customer request Level 0, Level 1R, Level 1Gs, 1Gp, and Level 1Gt Data Products corresponding to sub-areas within the heritage WRS-2 path/row scenes.
- 2.4.2.b** The smallest data product granule available from the LDCM shall be one-quarter of a WRS-2 scene.

### **2.4.3 Floating Sub-Interval Products**

Unprocessed LDCM digital image data acquired contiguously along an orbital path are herein referred to as a data interval.

**2.4.3.a** The LDCM shall produce and distribute at customer request Level 0, Level 1R, Level 1Gs, Level 1Gp, and Level 1Gt Data Products for contiguous sub-intervals within a data interval.

**2.4.3.b** The largest sub-interval Level 1R, Level 1Gs, Level 1Gp, and Level 1Gt data product available for the LDCM shall cover at least five WRS-2 scenes along an orbital path.

**2.4.3.c** The largest sub-interval available for Level 0 products for the LDCM shall cover at least 35 WRS-2 scenes along an orbital path.

## **2.5 LDCM Data Product Formats**

### **2.5.1 Level 0 and Level 1R LDCM Data Product Formats**

The LDCM shall produce and distribute Level 0 and Level 1R LDCM Data Products including but not necessarily limited to the unencapsulated Hierarchical Data Format (HDF).

### **2.5.2 Level 1Gs, Level 1Gp, and Level 1Gt LDCM Data Product Formats**

The LDCM shall produce and distribute Level 1Gs, Level 1Gp, and Level 1Gt LDCM Data Products in user selectable formats including, but not necessarily limited to:

**2.5.2.a** the unencapsulated Hierarchical Data Format (HDF)

**2.5.2.b** the Geographic Tagged Image File Format (GeoTIFF)

**2.5.2.c** the FAST L7A format.

## **2.6 LDCM Data Product Compression**

The LDCM shall produce and distribute uncompressed LDCM Data Products. Compressed data products may be offered as an option.

## **2.7 Data and Data Product Access and Availability**

### **2.7.1 LDCM Data Product Availability Time**

The LDCM shall provide the capability to:

- 2.7.1.a** Search the LDCM archive for archived, unprocessed LDCM digital image data within 48 hours of LDCM data acquisition by the LDCM sensor(s)
- 2.7.1.b** Order LDCM Data Products within 48 hours of LDCM data acquisition by the LDCM sensor(s).

### **2.7.2 LDCM Data Shipping Time**

#### **2.7.2.1 Small Orders**

Subject to the data product generation and distribution capacity specified in Section 2.7.6, the LDCM shall ship orders less than or equal to 10 LDCM Data Products within two business days after the order or within two business days after payment for the order has been cleared, whichever is later

#### **2.7.2.2 Large Orders**

Subject to the data product generation and distribution capacity specified in Section 2.7.6, the LDCM shall ship orders of greater than 10 LDCM Data Products at a rate of at least 10 Products shipped per day, starting two business days after the order or after payment for the order has been cleared, whichever is later. Customers will have the option to delay shipping until a full order is available.

### **2.7.3 LDCM Data Access and Data Product Ordering**

- 2.7.3.a** The LDCM shall provide the capability to search the archived LDCM data over the Internet on the basis of the metadata listed in 2.1.3.c.
- 2.7.3.b** The LDCM shall provide the capability to order LDCM Data Products from the results of searches.
- 2.7.3.c** Data product search results, metadata, and browse images for a single digital image granule shall be provided for viewing within 60 seconds of user query initiation for 90% of the queries made over a local area network.

#### **2.7.3.1 Metadata Access**

The LDCM shall provide the capability to:

**2.7.3.1.a** view archived LDCM metadata over the Internet for the purpose of searching

**2.7.3.1.b** view the metadata within 48 hours of acquisition of the associated digital image data by the LDCM sensor(s).

**2.7.3.2 Browse Image Access**

The LDCM shall provide the capability to:

**2.7.3.2.a** view archived LDCM browse images over the Internet for the purpose of searching.

**2.7.3.2.b** view the browse images within 48 hours of acquisition of the associated digital image data by the LDCM sensor(s).

**2.7.4 LDCM Data Product Ordering Mechanisms**

The LDCM shall provide the capability to order LDCM Data Products by the following mechanisms:

**2.7.4.a** over the Internet

**2.7.4.b** telephone

**2.7.4.c** facsimile machine

**2.7.4.d** written request

**2.7.4.e** email request.

**2.7.5 LDCM Data Product Distribution**

**2.7.5.a** The LDCM shall distribute LDCM Data Products on standard physical media.

**2.7.5.b** The LDCM shall electronically transmit LDCM Data Products at the request of the person ordering the products.

**2.7.6 LDCM Data Product Generation and Distribution Capacity**

The LDCM shall be capable of generating and distributing an average of 100 (over a 90 day period), with a peak capacity of 250, WRS-2 scene equivalents per day in any combination of data product types.

## **2.8 Algorithm and LDCM Data Product Documentation**

### **2.8.1 Archive and Product Generation Algorithms**

Algorithms used to produce the LDCM Data and Products listed in Sections 2.1 and 2.2 shall be documented, and made available to the extent allowable by U.S. export laws and regulations.

The documented algorithms shall include, but not be limited to,

**2.8.1.a** algorithms applied to radiometric correction

**2.8.1.b** radiometric artifact correction

**2.8.1.c** geolocation

**2.8.1.d** geometric correction

**2.8.1.e** sampling or resampling for cartographic registration.

### **2.8.2 Compression Algorithms**

Algorithms used for compression and decompression of unprocessed LDCM digital image data shall be documented, and made available to the extent allowable by U.S. export laws and regulations.

### **2.8.3 Product Specifications**

The specifications of LDCM data products and formats shall be documented, with the documentation available publicly.

## **2.9 Short-Term and Long-Term LDCM Data Archives**

### **2.9.1 Active Data Archival**

**2.9.1.a** The LDCM shall maintain the LDCM active archive for the life of the LDCM.

**2.9.1.b** The LDCM shall archive the data specified in Section 2.1 for the life of the LDCM.

**2.9.1.c** The LDCM shall produce and distribute the data products specified in Section 2.2 for the life of the LDCM.

### **2.9.2 Long-Term LDCM Data Archival**

**2.9.2.a** The LDCM shall provide a copy of all LDCM data, described in Section 2.1, procured or otherwise acquired by the U.S. Government under this contract, to the United States Geological

Survey (USGS) Earth Resources Observation System (EROS) Data Center (EDC).

- 2.9.2.b** The LDCM data, as described in Section 2.1, shall be delivered to the USGS EDC long-term archive within 48 hours after initial archiving.

### **3.0 LDCM Spatial Coverage and Temporal Resolution**

The archived, unprocessed LDCM digital image data provides substantially cloud-free, sun-lit, multispectral digital image coverage of the Earth's land areas on a seasonal basis, as defined in the following sections.

#### **3.1 Spatial Coverage**

The LDCM shall be capable of obtaining unprocessed LDCM digital image data for every point on the Earth's continental and coastal surfaces between  $\pm 81.8^\circ$  latitude.

##### **3.1.1 LDCM Global Archive Coverage**

This section includes requirements for coverage area, temporal frequency, and overall volume of data captured for the LDCM global archive(s), and does not include any requirement for International Cooperators.

###### **3.1.1.1 Daily LDCM Global Archive Coverage**

The unprocessed LDCM digital image data captured into the LDCM active and long term archive(s) shall provide an average daily coverage of at least 250 full WRS-2 (see 2.4.1) land scenes per any 90 day period.

WRS-2 land scenes are defined in the WRS Land Database, Revision 2.1, to include continental regions, coastal areas, islands, ice caps, and reefs.

###### **3.1.1.2 LDCM Global Archive Acquisition Strategy**

The LDCM shall implement a WRS-2 scene acquisition strategy such that the distribution of acquisition priority scores from archived scenes during any 16 day cycle has an equal or higher mean and median compared to the distribution provided by the Landsat-7 Long Term Acquisition Plan (LTAP) and scheduler, where "acquisition priority scores" refers to the science acquisition priorities calculated by the LTAP, as defined in the Appendix to this specification.

###### **3.1.1.3 Acquisition Priority Updates**

The LDCM shall update the LDCM acquisition strategy every 90 days, using base priorities and acquisition windows (defined in the Appendix to this specification) supplied by the government.

#### **3.1.2 Minimum Cross-Track Extent**

The unprocessed LDCM digital image data stored in the LDCM archive shall have a minimum cross-track extent of 185 km.

#### **3.1.3 WRS-2 Orientation**

The unprocessed LDCM digital image data shall be acquired in accordance with the Worldwide Reference System 2 (WRS-2) grid, such that the swath center of

the unprocessed LDCM digital image data shall be within 5 km of the center of the corresponding WRS-2 path.

### **3.2 Special Acquisitions**

#### **3.2.1 United States Coverage**

Archived LDCM data shall provide coverage of the fifty United States and the District of Columbia and their coastal areas at least once every 16 days or less, regardless of cloud cover, subject to the solar zenith requirement 3.3.1.1.

#### **3.2.2 High-Priority Target Coverage**

The LDCM shall acquire and archive LDCM data for up to twelve of the 250 WRS-2 scenes per day for high-priority targets of opportunity (e.g. natural disasters, volcanic eruptions, etc), which will be identified by the Government at least 24 hours prior to acquisition, and which may have individual requirements for predicted cloud cover.

### **3.3 Solar Illumination**

The LDCM data archive shall be composed of both daylight and night data, consisting primarily of daylight LDCM data with a limited amount of nighttime coverage for specific targets, as defined in the following sections.

#### **3.3.1 Global Daylight Coverage**

##### **3.3.1.1 Solar Zenith Angle**

LDCM data acquired in daylight for the LDCM archive shall be acquired when the solar zenith angle is less than 88°.

##### **3.3.1.2 Local Solar Time**

LDCM data collected along the equator shall be collected at 10 am (+/- 15 minutes), local solar time.

#### **3.3.2 Night Images**

**3.3.2.a** The LDCM shall acquire and archive all bands for up to 25 of the 250 WRS-2 scenes at night during any 24-hour period for priority targets such as volcanic activity, calibration targets, and fires. Specific targets will be provided by the Government at least 24 hours in advance of acquisition.

**3.3.2.b** The LDCM shall be capable of acquiring up to 10 contiguous night WRS-2 scenes during any 24 hour period.

### **3.4 Viewing Geometry; Maximum Viewing Zenith Angle**

The LDCM data archive shall contain unprocessed LDCM digital image data acquired with viewing zenith angles less than or equal to 10°.



### **4.0 LDCM Spectral Bands**

The LDCM shall acquire and archive multispectral digital image data for the spectral bands listed in Table 4.1-1.

#### **4.1 Spectral Band Widths**

**4.1.a** The full-width-half-maximum (FWHM) points of the relative spectral radiance response curve for each spectral band shall fall within the range of the minimum 50% lower band edge and the maximum 50% upper band edge as listed in Table 4.1-1.

**4.1.b** The bands shall be located so as to avoid atmospheric absorption features, where possible.

**Table 4.1-1 Spectral bands and band widths**

#	Band	Center Wavelength (nm)	Center Wavelength Tolerance (±nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)	Band Heritage/ Usage
1	Coastal Aerosol (Optional)	--	--	see	Section	9
2	Blue	482	5	450	515	ETM+ Band 1
3	Green	562	5	525	600	ETM+ Band 2
4	Red	655	5	630	680	ETM+ Band 3
5	NIR	865	5	845	885	ETM+ Band 4/ALI
6	SWIR 1	1610	10	1560	1660	ETM+ Band 5
7	SWIR 2*	2200	10	2100	2300	ETM+ Band 7
8	Sharpening **	590	10	500	680	ETM+ Pan Band/ALI
9	Cirrus (Optional)	--	--	see	Section	9
10	Thermal 1 (Optional)	--	--	see	Section	8
11	Thermal 2 (Optional)	--	--	see	Section	8

\* Minimum bandwidth is 180 nm for band 7

\*\* The band may be panchromatic with a center wavelength as specified and a bandwidth of at least 160 nm or a red band with band 4 specification

## **4.2 Spectral Band Shape**

### **4.2.1 Spectral Flatness**

#### **4.2.1.1 Flatness Between Band Edges**

The system relative spectral radiance response between the lower band edge (lowest wavelength with 0.5 response) and the upper band edge (highest wavelength with 0.5 response) shall have the following properties:

##### **4.2.1.1.1 Average Response**

The average response shall be greater than 0.8.

##### **4.2.1.1.2 Minimum Response**

No value shall be below 0.4.

#### **4.2.1.2 Flatness Between 80% response points**

The system relative spectral radiance response between the minimum wavelength with a 0.8 response and the maximum wavelength with a 0.8 response point shall always exceed 0.7.

### **4.2.2 Out of Band Response**

**4.2.2.a** The ratio of the integrated response beyond the 1% response points to the integrated response between the 1% response points shall be less than 2%. The integrated responses will be weighted by the solar exoatmospheric irradiance. The 1% response points are the points closest to the center wavelength where the response first drops to 1% of the peak response on each side of the center wavelength.

**4.2.2.b** Additionally the value of out of band response shall not exceed 0.1% at any wavelength more than 50 nm for all VNIR bands and 100 nm for all SWIR and sharpening bands from the corresponding 50% response band edge. If a red band is used for sharpening then Band 4 out of band requirements apply.

### **4.2.3 Edge Slope**

**4.2.3.a** The wavelength interval between the first 5% and the first 50% of peak response and the last 50% and the last 5% of peak response ranges shall not exceed the values in Table 4.2.3-1.

**4.2.3.b** The wavelength interval between the 1% response points and the corresponding 50% response band edge shall not exceed the values in Table 4.2.3-1.

**Table 4.2.3-1 Edge Slope Intervals for LDCM bands**

#	Band	Lower Edge Slope Interval 1% to 50% (nm)	Lower Edge Slope Interval 5% to 50% (nm)	Upper Edge Slope Interval 50% to 5% (nm)	Upper Edge Slope Interval 50% to 1% (nm)
1	Coastal Aerosol (Optional)	--	see	Section	9
2	Blue	25	20	20	25
3	Green	25	20	20	25
4	Red	25	20	15	20
5	NIR	25	20	15	20
6	SWIR 1	40	30	30	40
7	SWIR 2	50	40	40	50
8	Sharpening*	50	40	40	50
9	Cirrus (Optional)	--	see	Section	9
10	Thermal 1 (Optional)	--	see	Section	8
11	Thermal 2 (Optional)	--	see	Section	8

\* If a red band is used for sharpening, then Band 4 edge slope requirements apply.

#### 4.3 Spectral Uniformity

The bandwidth shall vary by no more than  $\pm 3\%$  across pixels within a band. Additionally see Section 6.2.3.

#### 4.4 Spectral Stability

Band center wavelengths and band edges shall not change by more  $\pm 2$  nm over the expected life of the mission.

#### 4.5 Spectral Band Simultaneity

For any point within a single scene observed by the LDCM, the LDCM shall acquire data for all spectral bands within a two-minute period.

## **5.0 LDCM Spatial Resolution**

### **5.1 Multispectral Ground Sample Distance**

- 5.1.a** Unprocessed LDCM digital image data shall provide a pixel-to-pixel increment equivalent to a ground sampling distance (GSD) of 30 m or less across the WRS-2 scene for LDCM spectral bands 2, 3, 4, 5, 6, and 7.
- 5.1.b** LDCM Level 1R digital image data shall provide a pixel-to-pixel increment equivalent to a ground sampling distance (GSD) of 30 m or less across the WRS-2 scene for LDCM spectral bands 2, 3, 4, 5, 6, and 7.

### **5.2 Sharpening Band Ground Sample Distance**

- 5.2.a** Unprocessed LDCM digital image data shall provide a single sharpening band, LDCM spectral band 8, with a pixel-to-pixel increment equivalent to a GSD of 15 m or less across the WRS-2 scene.
- 5.2.b** LDCM Level 1R digital image data shall provide a pixel-to-pixel increment equivalent to a GSD of 15 m or less across the WRS-2 scene for the single sharpening band, LDCM spectral band 8.

### **5.3 Edge Response**

The mean relative edge response slope in the in-track and cross-track directions (mean of slope between 40%-60%) for Level 1R digital image data shall conform to the criteria described in the following subsections.

Note: Table 5.3-1 lists the bands, their maximum allowable GSD, and the minimal edge slope. The edge response, in the context below, is the normalized response of the imaging system to an edge. That is, the edge response is normalized so that the mean minimum edge response is set to zero and the mean maximum response is set to 100%.

**Table 5.3-1 GSD / Minimum Slope Specification**

#	Band	Type	Maximum GSD	Slope
1	Coastal Aerosol (optional)	see	Section	9
2	Blue	Standard	30 m	.027 / m
3	Green	Standard	30 m	.027 / m
4	Red	Standard	30 m	.027 / m
5	NIR	Standard	30 m	.027 / m
6	SWIR 1	Standard	30 m	.027 / m
7	SWIR 2	Standard	30 m	.027 / m
8	Sharpening	Sharpening	15 m	.054 / m
9	Cirrus (optional)	see	Section	9
10	Thermal 1 (optional)	see	Section	8
11	Thermal 2 (optional)	see	Section	8

#### **5.3.1 Standard Band Edge Response Slope**

The mean relative edge response slope for LDCM spectral bands 2, 3, 4, 5, 6, and 7 (<30 m GSD) shall exceed 0.027/meter for Level 1R digital image data across the entire Field-of-View.

#### **5.3.2 Sharpening Band Edge Response Slope**

The mean relative edge response slope for the sharpening band, LDCM spectral band 8 (<15 m GSD), shall exceed 0.054/meter for Level 1R digital image data across the entire Field-of-View.

#### **5.3.3 Edge Response Overshoot**

The overshoot of any edge response for all bands shall not exceed 5% for Level 1R digital image data.

#### **5.3.4 Edge Response Uniformity**

The mean relative edge response slope shall not vary by more than 10% in any band across the Field-of-View and by not more than 20% between LDCM spectral bands 2,3,4,5,6,and 7 for Level 1R digital image data.

### **5.4 Aliasing**

#### **5.4.1 Level 1R Product Aliasing**

The product of the mean relative edge response slope and the GSD shall be less than 1.0 for Level 1R digital image data for both the in-track and cross track directions.

#### 5.4.2 Level 1G Product Aliasing

The product of the mean relative edge response slope in Level 1G digital image data, resampled using the cubic convolution method, and the maximum GSD specified in Table 5.3-1 shall be less than 1.0 for both the in-track and cross track directions.

### 5.5 Stray Light Rejection and Internal Light Scattering

#### 5.5.1 Point Source Transmittance (PST)

For any detector in the sensor and for all bands, the normalized point source transmittance (PST) (peak point source response normalized to unity) shall be less than the values given in Table 5.5-1 for the corresponding off-field angles over the entire field-of-view of the system.

**Table 5.5-1 PST Specification**

Off-Field Angles	PST for all Bands
$.3^{\circ} < \Theta < 1^{\circ}$	$<10^{-2}$
$1^{\circ} < \Theta < 3^{\circ}$	$<10^{-3}$
$3^{\circ} < \Theta < 10^{\circ}$	$<10^{-4}$
$10^{\circ} < \Theta < 20^{\circ}$	$<10^{-5}$
$20^{\circ} < \Theta < 25^{\circ}$	$<10^{-6}$

#### 5.5.2. Total Integrated Optical Scatter (TIS)

The total integrated scatter for 1 degree or greater for a point target imaged onto a detector in any band shall be less than 1%.

## 6.0 LDCM Radiometry

### 6.1 Absolute Radiometric Accuracy

The digital values in a Level 1 data product shall be linearly scaled to at-aperture spectral radiance with an uncertainty less than or equal to 5% (1 sigma) **with a goal of 3%** (1 sigma) across the range of 0.3  $L_{\text{typical}}$  to 0.9  $L_{\text{max}}$  (Table 6.1-1) with all accuracies established relative to National Institute for Standards and Technology (NIST) standards.

**Table 6.1-1 Radiance/Temperature Levels for Signal-to-Noise Ratio (SNR) Requirements and Saturation Radiances**

#	Band	Radiance Level for SNR, L (W/m <sup>2</sup> sr μm)		Saturation Radiances, L <sub>Max</sub> (W/m <sup>2</sup> sr μm)	
		Typical, L <sub>Typical</sub>	High, L <sub>high</sub>	Requirement	Goal
1	Coastal Aerosol (Optional)	--	see	Section 9	--
2	Blue	40	190	592	--
3	Green	30	194	553	--
4	Red	22	150	470	--
5	NIR	14	150	285	--
6	SWIR 1	4.0	32	72.5	145
7	SWIR 2	1.7	11	24.7	49.4
8	Sharpening*	23	156	524	-
9	Cirrus (Optional)	--	see	Section 9	--
10	Thermal 1 (Optional)	--	see	Section 8	--
11	Thermal 2 (Optional)	--	see	Section 8	--

\* If a red band is used for sharpening, then Band 4 Radiance levels apply for SNR and Saturation Radiance requirements.

### 6.2 Radiometric Signal to Noise

#### 6.2.1 Pixel Signal-to-Noise Ratios (SNRs)

SNRs required for all LDCM Level 1 digital image data and for each spectral band are listed in Table 6.1-1 and 6.2.1-1.

**6.2.1.a** 50% of the pixels shall meet or exceed these SNR values.

**6.2.1.b** 99% of the pixels shall exceed 80% of these values.

**Table 6.2.1-1 SNR Requirements and Goals**

#	Band	SNR Requirements		SNR Goals	
		At $L_{\text{Typical}}$	At $L_{\text{High}}$	At $L_{\text{Typical}}$	At $L_{\text{High}}$
1	Coastal Aerosol (Optional)	--	see	Section 9	--
2	Blue	130	360	190	540
3	Green	100	390	210	830
4	Red	90	340	170	670
5	NIR	90	460	150	780
6	SWIR 1	100	540	--	--
7	SWIR 2	100	510	180	700
8	Sharpening*	80	230	170	500
9	Cirrus (Optional)	--	see	Section 9	--
10	Thermal 1 (Optional)	--	see	Section 8	--
11	Thermal 2 (Optional)	--	see	Section 8	--

\* If the sharpening band is chosen to be a red band with band 4 spectral specifications, then the SNR requirements are the band 4 SNR requirements divided by 2 and evaluated at the Band 4  $L_{\text{typical}}$  and  $L_{\text{high}}$  radiance values.

## 6.2.2 Quantization Noise Limit

### 6.2.2.1 Unprocessed LDCM Digital Image Data Quantization

The unprocessed LDCM digital image data SNR performance shall not be quantization noise limited, i.e. at zero radiance and above, system noise shall be greater than or equal to 0.5 Digital Number.

### 6.2.2.2 LDCM Data Product Quantization

LDCM Level 0 and Level 1 digital image data SNR performance shall not be quantization noise limited, i.e. at zero radiance and above, system noise shall be greater than or equal to 0.5 Digital Number.

## 6.2.3 Pixel-to-Pixel Uniformity

For a uniform source above  $2 \cdot L_{\text{typical}}$  the standard deviation of the calibrated values across pixels within a line of Level 1R digital image data within a band shall not exceed 0.25% of the average radiance for bands 2-7 and 0.5% of the



average radiance for band 8. Temporal noise may be averaged to verify compliance with this specification.

Note: This requirement applies for target radiances with spectral characteristics as follows: the spectral radiance of the source used in pre-launch calibration, spectral radiance from bare soil as observed through a dry atmosphere, spectral radiance proportional to the exoatmospheric solar irradiance, and spectral radiance from a dense vegetation target as observed through a moist atmosphere (See Figure 6.2.3-1 and Top of Atmosphere Radiance Values , MODTRAN 4 Model table values, Reference d).

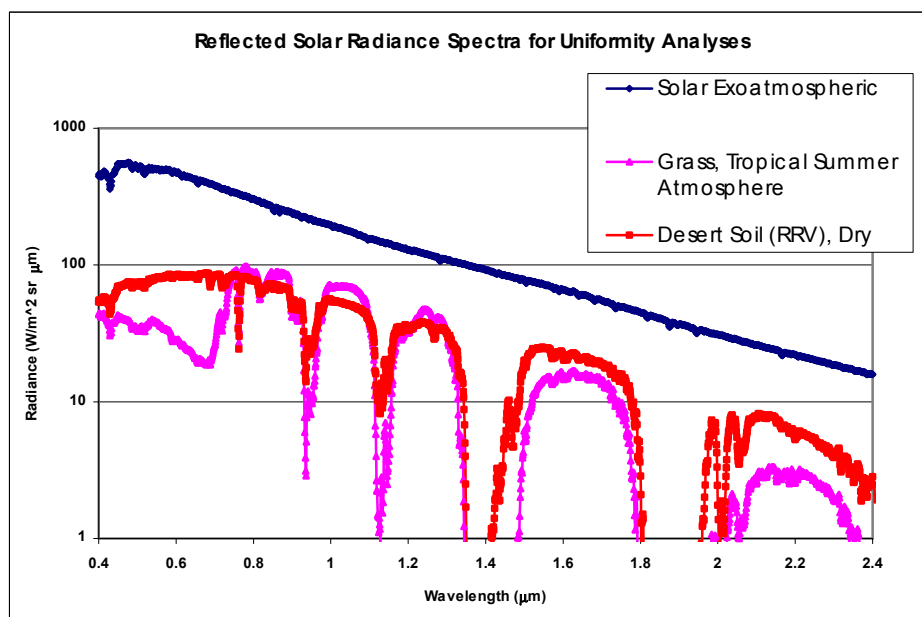


Figure 6.2.3-1

#### 6.2.4 Coherent Noise

The magnitude of the autocorrelation of a dark (zero-radiance) scene, computed after subtraction of detector-by-detector direct current offset, and normalized to 1.0 at zero lag, shall not exceed 0.25 at any non-zero spatial lag.

#### 6.3 Dynamic Range

The LDCM Level 0 and Level 1 digital image data shall cover, without saturating, signals up to the  $L_{max}$  as shown in table 6.1-1. Note: For bands 2-8, this corresponds to the radiance reflected off of a Lambertian target of 100% reflectance illuminated by the sun at a solar zenith angle of  $20^\circ$ .

#### 6.4 Polarization Sensitivity

The source of the data (excluding the thermal band) shall be insensitive to linear polarization, such that the polarization factor, defined as  $PF = (I_{max} - I_{min}) / (I_{max} + I_{min})$ , is less than 0.05.

### **6.5 Radiometric Stability**

The LDCM Level 1 digital image data for radiometrically constant targets with radiances greater than or equal to  $L_{\text{typical}}$  shall not differ by more than  $\pm 1\%$  over any time up to 16 days nor by more than  $\pm 2\%$  in any period between 16 days and five years.

### **6.6 Image Artifacts**

#### **6.6.1 Bright Target Recovery**

The unprocessed data in the archive shall be such that the recovery region around an image pixel which has been exposed to a radiance level of less than or equal to 1.5 times that of the source sensor's saturation level shall be contained within a 7 x 7 pixel region centered on the exposed pixel.

#### **6.6.2 Pixel-to-Pixel Crosstalk**

The crosstalk-induced artifacts in neighboring pixels caused by regions of pixels having radiance levels less than the saturation level and which are more than ten pixels away, shall not exceed 1%, in total, after radiometric correction.

## 7.0 LDCM Geometric Precision, Geolocation, and Cartographic Registration

### 7.1 Band-to-Band Registration

Level 1G (radiometrically and geometrically corrected) data products shall exhibit band-to-band registration accuracy for targets at the Earth's surface as specified in the following sections.

Notes: Level 1G products that are created using the nearest neighbor resampling method are treated separately for purposes of band-to-band registration due to the inability to correct for sub-pixel effects when using this method.

#### 7.1.1 Level 1G Nearest Neighbor Product Band-to-Band Registration

Corresponding pixels from the digital images of the spectral bands in Level 1G data products created using nearest neighbor resampling, as specified in section 2.3.2.a, shall be co-registered with an uncertainty of 15 meters or less, ***with a goal of 3 meters or less***, in the line and sample directions at the 90% confidence level for target areas within 100 meters of the WGS84 (G873 or current version) Earth ellipsoid surface.

#### 7.1.2 Level 1G Data Product Band-to-Band Registration

Corresponding pixels from the digital images of the spectral bands in Level 1G data products created using the resampling methods specified in sections 2.3.2.b through 2.3.2.d, shall be co-registered with an uncertainty of 4.5 meters or less, ***with a goal of 3 meters or less***, in the line and sample directions at the 90% confidence level for target areas within 100 meters of the WGS84 (G873 or current version) Earth ellipsoid surface.

### 7.2 Image-to-Image Registration

Two Level 1G data products of the same area, derived from data acquired on different dates, shall be capable of being co-registered with an uncertainty less than or equal to 0.5 pixel in the line and sample directions at the 90% confidence level when image-to-image correlation is applied to data from the same spectral band. This requirement applies to data from all spectral bands.

### 7.3 Level 1Gs Product Geodetic Accuracy

#### 7.3.1 Level 1Gs Product Absolute Geodetic Accuracy

The pixels for targets at the Earth's topographic surface in the Level 1Gs data products shall be located relative to the WGS84 geodetic reference system, G873 or current version, with an uncertainty less than or equal to 65 meters (90% circular error) ***with a goal of 50 meters (90% circular error)***, excluding terrain effects. This specification applies to the horizontal error of ground control points measured in the 1Gs image, after compensation for control point height.

### **7.3.2 Level 1Gs Product Relative Geodetic Accuracy**

The pixels for targets at the Earth's topographic surface in the Level 1Gs data products shall be located relative to the WGS84 geodetic reference system, G873 or current version, with an uncertainty less than or equal to 25 meters (90% circular error), excluding terrain effects, over an area of 180 km by 180 km, after the removal of constant offsets. This specification applies to the standard deviation of ground control points measured in the 1Gs image, after compensation for control point height.

### **7.4 Level 1Gp Product Geodetic Accuracy**

The pixels for targets at the Earth's topographic surface in the Level 1Gp data products shall be located relative to the WGS84 geodetic reference system, G873 or current version, with an uncertainty less than or equal to 12 meters (90% circular error), excluding terrain effects.

### **7.5 Level 1Gt Product Geodetic Accuracy**

The pixels for targets at the Earth's topographic surface in the Level 1Gt orthorectified data products shall be located relative to the WGS84 geodetic reference system, G873 or current version, with an uncertainty less than or equal to 12 meters (90% circular error), including compensation for terrain effects.

## 8.0 LDCM Thermal Band Option Requirements

The requirements in this section are for a separate design and cost option as per 427-SOW-00002, LDCM Formulation Phase Statement of Work.

### 8.1 LDCM Data and Data Products

The requirements of Section 2 shall apply to the thermal band.

#### 8.1.1 Resampled Grid Cell Size Characteristics for Thermal Bands

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product thermal bands shall be resampled into a selected cartographic projection system using customer-specified grid cell (i.e., resampled output pixel) sizes, with the characteristics defined in the following subsections.

##### 8.1.1.1 Selectable Resampled Grid Cell Sizes for Thermal Bands

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product grid cell sizes shall be independently selectable for the following band group:

###### 8.1.1.1.a Thermal bands (bands 10, 11)

##### 8.1.1.2 Resampled Grid Cell Size Range for Thermal Bands

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product thermal band grid cell sizes shall be selectable with the minimum range specified in Table 8.1.1.2-1. Note: product throughput will be based upon the nominal grid cell size in Table 8.1.1.2-1.

**Table 8.1.1.2-1: Resampled Grid Cell Sizes For Thermal Bands**

<b>Band Group</b>	<b>Thermal Bands (optional)</b>
Size Range	30 m - 250 m
Nominal Size	120 m

##### 8.1.1.3 Resampled Grid Cell Size Increment for Thermal Bands

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product grid cell sizes shall be selectable in increments of 0.001 meters or smaller.

### 8.2 LDCM Spatial Coverage and Temporal Resolution

The requirements of Section 3 shall apply to the thermal band.

### 8.3 LDCM Thermal Spectral Bands

The LDCM shall acquire and archive data for the thermal bands listed in Table 8.3-1.

### 8.3.1 Thermal Spectral Band Widths

The FWHM points of the relative spectral radiance response curve for each band shall fall within the range of the minimum 50% lower band edge and the maximum 50% upper band edge as listed in Table 8.3-1.

**Table 8.3-1 Thermal Spectral Bands and Bandwidths**

#	Band	Center Wavelength (nm)	Center Wavelength Tolerance ( $\pm$ nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)	Band Heritage/ Usage
10	Thermal 1	10800	100	10300	11300	ETM+/AVHRR Surface Temp
11	Thermal 2	12000	100	11500	12500	ETM+/AVHRR Surface Temp

### 8.3.2 Spectral Characteristics

#### 8.3.2.1 Spectral Flatness

##### 8.3.2.1.1 Flatness Between Band Edges

The system relative spectral radiance response between the lower band edge (lowest wavelength with 0.5 response) and the upper band edge (highest wavelength with 0.5 response) shall have the following properties:

##### 8.3.2.1.1.1 Average Response

The average response shall be greater than 0.8.

##### 8.3.2.1.1.2 Minimum Response

No value shall be below 0.4.

##### 8.3.2.1.2 Flatness Between 80% response points

The system relative spectral radiance response between the minimum wavelength with a 0.8 response and the maximum wavelength with a 0.8 response point shall always exceed 0.7.

#### 8.3.2.2 Out of Band Response

The ratio of the integrated response beyond the 1% response points to the integrated response between the 1% response points shall be less than 2% between 3000 and 20000 nm and less than 0.5% below 3000 nm. The integrated responses will be weighted by the radiance from a 300k blackbody summed with the radiance from a Lambertian surface of 100% reflectance illuminated by the sun at a zenith angle of 30°. The 1%

response points are the points closest to the center wavelength where the response first drops to 1% of the peak response on each side of the center wavelength.

### 8.3.2.3 Edge Slope

**8.3.2.3.a** The wavelength interval between the first 5% and the first 50% of peak response and the last 50% and the last 5% of peak response ranges shall not exceed the values in Table 8.3.2.3-1.

**8.3.2.3.b** The wavelength interval between the 1% response points and the corresponding 50% response band edge shall not exceed the values in Table 8.3.2.3-1.

**Table 8.3.2.3-1 Edge Slope Intervals for LDCM Thermal bands**

#	Band	Lower Edge Slope Interval 1% to 50% (nm)	Lower Edge Slope Interval 5% to 50% (nm)	Upper Edge Slope Interval 50% to 5% (nm)	Upper Edge Slope Interval 50% to 1% (nm)
10	Thermal 1	300	200	200	300
11	Thermal 2	300	200	200	300

### 8.3.2.4 Spectral Uniformity

The bandwidth shall vary by no more than  $\pm 3\%$  across pixels within a band. Additionally see Section 8.5.2.3.

### 8.3.2.5 Spectral Stability

Band center wavelengths and band edges shall not change by more  $\pm 20$  nm over the expected life of the mission.

### 8.3.2.6 Spectral Band Simultaneity

**8.3.2.6.a** For any point within a single scene observed by the LDCM, the LDCM shall acquire data for all spectral bands within a two-minute period.

**8.3.2.6.b** The data for the two thermal bands shall be acquired within 10 seconds of each other.

## 8.4 LDCM Thermal Spectral Band Spatial Resolution

### 8.4.1 Thermal Bands Ground Sample Distance

**8.4.1.a** Unprocessed LDCM digital image data shall provide a pixel-to-pixel increment equivalent to a GSD 120m or less for the thermal bands across the WRS-2 scene.

**8.4.1.b** LDCM Level 1R digital image data shall provide a pixel-to-pixel increment equivalent to a GSD 120m or less for the thermal bands across the WRS-2 scene.

### 8.4.2 Thermal Band Edge Response Slope

The mean relative edge response slope for the thermal bands (< 120m), shall exceed 0.006/meter for Level 1R digital image data across the entire Field-of-View. See Table 8.4.2-1.

**Table 8.4.2-1 Thermal Band Edge Response Slope**

#	Band	Type	Maximum GSD	Slope
10	Thermal 1	Thermal	120 m	0.006/m
11	Thermal 2	Thermal	120 m	0.006/m

### 8.4.3 Edge Response Overshoot and Aliasing

The requirements of 5.3.3 and 5.4 shall apply to the thermal bands.

### 8.4.4 Thermal Band Edge Response Uniformity

The mean relative edge response slope shall not vary by more than 10% in any band across the Field-of-View and by not more than 20% between the LDCM spectral bands 10 and 11 (thermal bands) for Level 1R digital image data.

## 8.5 LDCM Thermal Spectral Band Radiometry

### 8.5.1 Absolute Radiometric Accuracy

The digital values in a Level 1 data product shall be linearly scaled to at-aperture spectral radiance with an uncertainty less than or equal to 2%(1 sigma) **with a goal of 1% (1 sigma)** across the range of radiances corresponding to 240K to 330K blackbodies with all accuracies established relative to NIST standards.

### 8.5.2 Radiometric Precision

#### 8.5.2.1 Pixel Noise Equivalent Delta Temperatures



Noise Equivalent Delta Temperatures (NEDT) required for LDCM Level 1 digital image data and for each thermal band are listed in Table 8.5.2.1-1 and 8.5.2.1-2. 50% of the pixels shall be less than or equal to these NEDT values, 99% of the pixels shall be less than or equal to 1.2 times these values.

**Table 8.5.2.1-1 Temperatures for Noise and Saturation for Thermal Bands**

#	Band	Temperatures for NEDT (K)		Saturation Temperatures, T <sub>Max</sub> (K)	
		Typical, T <sub>Typical</sub>	High, T <sub>High</sub>	Requirement	Goal
10	Thermal 1	300K	320K	340K	425K
11	Thermal 2	300K	320K	340K	425K

**Table 8.5.2.1-2 Noise Equivalent Delta Temperatures for Thermal Bands**

#	Band	NEDT Requirements		NEDT Goals	
		At T <sub>Typical</sub>	At T <sub>High</sub>	At T <sub>Typical</sub>	At T <sub>High</sub>
10	Thermal 1	0.5K	0.42K	0.25K	0.21K
11	Thermal 2	0.5K	0.42K	0.25K	0.21K

#### 8.5.2.2 Quantization Noise Limit

The requirements of Section 6.2.2 shall apply to the thermal bands.

#### 8.5.2.3 Pixel-to-Pixel Uniformity

For a uniform source above the radiance corresponding to a blackbody temperature of 240K, the standard deviation of the calibrated values across pixels within a line of LDCM Level 1R digital image data within a band shall not exceed 0.5% (**0.25% goal**) of the average radiance. This requirement applies for spectral radiances from 240K to 340K blackbody sources. Temporal noise may be averaged to verify compliance with this specification.

#### 8.5.2.4 Coherent Noise

The requirements of Section 6.2.4 shall apply to the thermal bands.

### 8.5.3 Dynamic Range

The dynamic range of the LDCM Level 0 and Level 1 digital image data shall be from the noise floor up to the TMAX as shown in Table 8.5.2-1. The equivalent blackbody temperatures of the noise floors of bands 10 and 11 are 143K at the

required NEDT (133K at the goal NEDT) and 133K at the required NEDT (126K at the goal NEDT), respectively.

#### 8.5.4 Radiometric Stability

The radiometrically calibrated LDCM Level 1 digital image data for radiometrically constant targets with radiances greater than or equal to the radiance of a 240K blackbody, shall not differ by more than  $\pm 0.5\%$  over any time up to 16 days nor by more than  $\pm 1\%$  in any period between 16 days and five years.

#### 8.5.5 Image Artifacts

The requirements of Section 6.6 shall apply to the thermal bands.

### 8.6 LDCM Geometric Precision, Geolocation and Cartographic Registration

#### 8.6.1 Band-to-Band Registration

Level 1G (radiometrically and geometrically corrected) data products exhibit band-to-band registration accuracy for targets at the Earth's surface as specified in the following sections.

##### 8.6.1.1 Level 1G Nearest Neighbor Product Band-to-Band Registration

Corresponding pixels from the digital images of the spectral bands in Level 1G data products created using the nearest neighbor resampling method, as specified in section 2.3.2.a, shall be co-registered with an uncertainty as specified in Table 8.6-1, in the line and sample directions at the 90% confidence level for target areas within 100 meters of the WGS84 (G873 or current version) Earth ellipsoid surface.

**Table 8.6-1: Level 1G Nearest Neighbor Band Registration Requirements**

Registration requirements for each band pair are found by reading down the appropriate column and across the appropriate row.	<b>Standard Bands 1, 2, 3, 4, 5, 6, 7, and 8</b>	<b>Cirrus Band 9 and Thermal Bands 10 and 11</b>
<b>Standard Bands 1, 2, 3, 4, 5, 6, 7, and 8</b>	15 meters (required) <i>3 meters (goal)</i>	60 meters (required) <i>12 meters (goal)</i>
<b>Cirrus Band 9 and Thermal Bands 10 and 11</b>	60 meters (required) <i>12 meters (goal)</i>	60 meters (required) <i>12 meters (goal)</i>

##### 8.6.1.2 Level 1G Data Product Band-to-Band Registration

Corresponding pixels from the digital images of the spectral bands in Level 1G data products created using the resampling methods specified in

sections 2.3.2.b through 2.3.2.d shall be co-registered with an uncertainty as specified in Table 8.6-2, in the line and sample directions at the 90% confidence level for target areas within 100 meters of the WGS84 (G873 or current version) Earth ellipsoid surface.

**Table 8.6-2: Level 1G Band Registration Requirements**

Registration requirements for each band pair are found by reading down the appropriate column and across the appropriate row.	<b>Standard Bands 1, 2, 3, 4, 5, 6, 7, and 8</b>	<b>Cirrus Band 9 and Thermal Bands 10 and 11</b>
<b>Standard Bands 1, 2, 3, 4, 5, 6, 7, and 8</b>	4.5 meters (required) <i>3 meters (goal)</i>	18 meters (required) <i>12 meters (goal)</i>
<b>Cirrus Band 9 and Thermal Bands 10 and 11</b>	18 meters (required) <i>12 meters (goal)</i>	18 meters (required) <i>12 meters (goal)</i>

#### **8.6.2 Thermal Spectral Band Registration and Geodetic Accuracy**

The requirements of Section 7.2-7.5 shall apply to the thermal bands.

## 9.0 LDCM Optional Reflective Bands

The requirements in this section are for separate design and cost options as per 427-SOW-00002, LDCM Formulation Phase Statement of Work.

### 9.1 LDCM Data and Data Products

The requirements of Section 2 shall apply to the optional reflective bands.

#### 9.1.1 Resampled Grid Cell Size Characteristics for Optional Reflective Bands

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product optional reflective bands shall be resampled into a selected cartographic projection system using customer-specified grid cell (i.e., resampled output pixel) sizes, with the characteristics defined in the following subsections.

##### 9.1.1.1 Selectable Resampled Grid Cell Sizes for Optional Reflective Bands

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product grid cell sizes shall be independently selectable for the following band groups:

**9.1.1.1.a** coastal/aerosol band (band 1)

**9.1.1.1.b** the cirrus band (band 9)

##### 9.1.1.2 Resampled Grid Cell Size Ranges

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product optional reflective band grid cell sizes shall be selectable with the minimum ranges specified in Table 9.1.1.2-1. Note: product throughput will be based upon the nominal grid cell sizes in Table 9.1.1.2-1.

**Table 9.1.1.2-1: Resampled Grid Cell Sizes**

<b>Band Group</b>	<b>Coastal/Aerosol (optional)</b>	<b>Cirrus Band (optional)</b>
Size Range	15 m - 60 m	30 m - 250 m
Nominal Size	30 m	120 m

##### 9.1.1.3 Resampled Grid Cell Size Increment

The LDCM Level 1Gs, Level 1Gp, and Level 1Gt product grid cell sizes shall be selectable in increments of 0.001 meters or smaller.

### 9.2 LDCM Spatial Coverage and Temporal Resolution

The requirements of Section 3 shall apply to the optional reflective bands.

### 9.3 LDCM Spectral Bands

The LDCM shall acquire and archive data for the optional reflective bands listed in Table 9.3.1-1.

#### 9.3.1 Reflective Bands and Band Width

The full-width-half-maximum (FWHM) points of the relative spectral radiance response curve for each spectral band shall fall within the range of the minimum 50% lower band edge and the maximum 50% upper band edge as listed in Table 9.3.1-1.

**Table 9.3.1-1 Reflective bands and band widths**

#	Band	Center Wavelength (nm)	Center Wavelength Tolerance ( $\pm$ nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)	Band Heritage/ Usage
1	Coastal/ Aerosol	443	2	433	453	ALI/MODIS
9	Cirrus*	1375	5	1360	1390	MODIS

\* Minimum bandwidth is 20 nm for band 9

### 9.3.2 Spectral Characteristics

#### 9.3.2.1 Spectral Flatness

##### 9.3.2.1.1 Flatness Between Band Edges

The system relative spectral radiance response between the lower band edge (lowest wavelength with 0.5 response) and the upper band edge (highest wavelength with 0.5 response) shall have the following properties:

##### 9.3.2.1.1.1 Average Response

The average response shall be greater than 0.8.

##### 9.3.2.1.1.2 Minimum Response

No value shall be below 0.4.

##### 9.3.2.1.2 Flatness Between 80% response points

The system relative spectral radiance response between the minimum wavelength with a 0.8 response and the maximum wavelength with a 0.8 response point shall always exceed 0.7.

### 9.3.2.2 Out of Band Response

**9.3.2.2.a** The ratio of the integrated response beyond the 1% response points to the integrated response between the 1% response points shall be less than 2%. The integrated responses will be weighted by the solar exoatmospheric irradiance. The 1% response points are the points closest to the center wavelength where the response first drops to 1% of the peak response on each side of the center wavelength.

**9.3.2.2.b** Additionally, the value of out of band response shall not exceed 0.1% at any wavelength more than 50 nm from the corresponding 50% response band edge.

### 9.3.2.3 Edge Slope

**9.3.2.3.a** The wavelength interval between the first 5% and the first 50% of peak response and the last 50% and the last 5% of peak response ranges shall not exceed the values in Table 9.3.2.3-1.

**9.3.2.3.b** The wavelength interval between the 1% response points and the corresponding 50% response band edge shall not exceed the values in Table 9.3.2.3-1.

**Table 9.3.2.3-1 Edge Slope Intervals for LDCM optional reflective bands**

#	Band	Lower Edge Slope Interval 1% to 50% (nm)	Lower Edge Slope Interval 5% to 50% (nm)	Upper Edge Slope Interval 50% to 5% (nm)	Upper Edge Slope Interval 50% to 1% (nm)
1	Coastal Aerosol	15	10	10	15
9	Cirrus	15	10	10	15

### 9.3.2.4 Spectral Uniformity

The bandwidth shall vary by no more than  $\pm 3\%$  across pixels within a band. Additionally see section 9.5.2.3.

### 9.3.2.5 Spectral Stability

Band center wavelengths and band edges shall not change by more  $\pm 2$  nm over the expected life of the mission.

#### **9.3.2.6 Spectral Band Simultaneity**

For any point within a single scene observed by the LDCM, the LDCM shall acquire data for all spectral bands within a two-minute period.

### **9.4 LDCM Spatial Resolution**

#### **9.4.1 Ground Sample Distance**

##### **9.4.1.1 Coastal/Aerosol Band Ground Sample Distance**

**9.4.1.1.a** Unprocessed LDCM digital image data shall provide a pixel-to-pixel increment equivalent to a ground sampling distance (GSD) of 30 m or less across the WRS-2 scene for LDCM spectral band 1 (refer to Table 9.3.1-1).

**9.4.1.1.b** LDCM Level 1R digital image data shall provide a pixel-to-pixel increment equivalent to a ground sampling distance (GSD) of 30 m or less across the WRS-2 scene for LDCM spectral band 1 (refer to Table 9.3.1-1).

##### **9.4.1.2 Cirrus Band Ground Sample Distance**

**9.4.1.2.a** Unprocessed LDCM digital image data shall provide a pixel-to-pixel increment equivalent to a GSD 120 m or less across the WRS-2 scene for LDCM spectral band 9 (refer to Table 9.3.1-1).

**9.4.1.2.b** LDCM Level 1R digital image data shall provide a pixel-to-pixel increment equivalent to a GSD 120 m or less across the WRS-2 scene for LDCM spectral band 9 (refer to Table 9.3.1-1).

#### **9.4.2 Edge Response**

The mean relative edge response slope in the in-track and cross-track directions (mean of slope between 40%-60%) for Level 1R digital image data shall conform to the criteria described in the following subsections.

Note: Table 9.4.2-1 lists the bands, their maximum allowable GSD, and the minimal edge slope. The edge response, in the context below, is the normalized response of the imaging system to an edge. That is, the edge response is normalized so that the mean minimum edge response is set to zero and the mean maximum response is set to 100%.

**Table 9.4.2-1 GSD / Minimum Slope Specification**

#	Band	Type	Maximum GSD	Slope
1	Coastal / Aerosol	Standard	30 m	.027 / m
9	Cirrus	Atmospheric	120 m	.006 / m

#### **9.4.2.1 Coastal/Aerosol Band Edge Response Slope**

The mean relative edge response slope for the coastal/aerosol band, LDCM spectral band 1 (< 30 m), shall exceed 0.027/meter for Level 1R digital image data across the entire Field-of-View.

#### **9.4.2.2 Cirrus Band Edge Response Slope**

The mean relative edge response slope for the cirrus band, LDCM spectral band 9 (< 120 m), shall exceed 0.006/meter for Level 1R digital image data across the entire Field-of-View.

#### **9.4.3 Edge Response Overshoot, Aliasing, and Stray Light Rejection**

The requirements of 5.3.3, 5.4, and 5.5 shall apply to the optional reflective bands.

#### **9.4.4 Band 1 Edge Response Uniformity**

The mean relative edge response slope shall not vary by more than 10% in any band across the Field-of-View and by not more than 20% between LDCM spectral bands 1,2,3,4,5,6,and 7 for Level 1R digital image data.

### **9.5 LDCM Radiometry**

#### **9.5.1 Absolute Radiometric Accuracy**

The digital values in a Level 1 data product shall be linearly scaled to at-aperture spectral radiance with an uncertainty less than or equal to 5% (1 sigma) *with a goal of 3%* (1 sigma) across the range of 0.3  $L_{\text{typical}}$  to 0.9  $L_{\text{max}}$  (Table 9.5.1-1), with all accuracies established relative to National Institute for Standards and Technology (NIST) standards.

**Table 9.5.1-1 Radiance Levels for SNR requirements and Saturation Radiances**

#	Band	Radiance Level for SNR , $L_{\square}$ (W/m <sup>2</sup> sr $\mu\text{m}$ )		Saturation Radiances , $L_{\text{Max}}$ (W/m <sup>2</sup> sr $\mu\text{m}$ )	
		Typical, $L_{\text{Typical}}$	High, $L_{\text{high}}$	Requirement	Goal
1	Coastal/ Aerosol	40	190	564	--
9	Cirrus	6.0	--	90	-



## 9.5.2 Radiometric Precision

### 9.5.2.1 Pixel Signal-to-Noise Ratios

Signal to noise ratios required for LDCM Level 1 digital image data and for each spectral band are listed in Table 9.5.1-1 and 9.5.2-1.

**9.5.2.1.a** 50% of the pixels shall meet or exceed these SNR values.

**9.5.2.1.b** 99% of the pixels shall exceed 80% of these values.

**Table 9.5.2-1 SNR Requirements and Goals**

#	Band	SNR Requirements		SNR Goals	
		At $L_{\text{Typical}}$	At $L_{\text{High}}$	At $L_{\text{Typical}}$	At $L_{\text{High}}$
1	Coastal/ Aerosol	130	290	150	340
9	Cirrus	130	--	150	--

### 9.5.2.2 Quantization Noise Limit

The requirements of Section 6.2.2 shall apply to the optional reflective bands.

### 9.5.2.3 Pixel-to-Pixel Uniformity

The requirements of Section 6.2.3 for bands 2-7 shall apply to the optional reflective bands.

### 9.5.2.4 Coherent Noise

The requirements of Section 6.2.4 shall apply to the optional reflective bands.

## 9.5.3 Dynamic Range

The LDCM Level 0 and Level 1 digital image data shall cover, without saturating, signals up to the  $L_{\text{max}}$  as shown in Table 9.5.1-1.

Note: For band 1, this corresponds to the radiance reflected off of a Lambertian target of 100% reflectance illuminated by the sun at a solar zenith angle of 20°.

## 9.5.4 Polarization Sensitivity, Radiometric Stability, and Image Artifacts

The requirements of Section 6.4, 6.5, and 6.6 shall apply to the optional reflective bands

## 9.6 LDCM Geometric Precision, Geolocation and Cartographic Registration

### 9.6.1 Level 1G Nearest Neighbor Product Band-to-Band Registration

Corresponding pixels from the digital images of the spectral bands in Level 1G data products created using the nearest neighbor resampling method, as specified in section 2.3.2.a, shall be co-registered with an uncertainty as specified in Table 9.6.1-1, in the line and sample directions at the 90% confidence level for target areas within 100 meters of the WGS84 (G873 or current version) Earth ellipsoid surface.

**Table 9.6.1-1: Level 1G Nearest Neighbor Band Registration Requirements**

Registration requirements for each band pair are found by reading down the appropriate column and across the appropriate row.	<b>Standard Bands 1, 2, 3, 4, 5, 6, 7, and 8</b>	<b>Cirrus Band 9 and Thermal Bands 10 and 11</b>
<b>Standard Bands 1, 2, 3, 4, 5, 6, 7, and 8</b>	15 meters (required) <i>3 meters (goal)</i>	60 meters (required) <i>12 meters (goal)</i>
<b>Cirrus Band 9 and Thermal Bands 10 and 11</b>	60 meters (required) <i>12 meters (goal)</i>	60 meters (required) <i>12 meters (goal)</i>

### 9.6.2 Level 1G Data Product Band-to-Band Registration

Corresponding pixels from the digital images of the spectral bands in Level 1G data products created using the resampling methods specified in sections 2.3.2.b through 2.3.2.d shall be co-registered with an uncertainty as specified in Table 9.6.2-1, in the line and sample directions at the 90% confidence level for target areas within 100 meters of the WGS84 (G873 or current version) Earth ellipsoid surface.

**Table 9.6.2-1: Level 1G Band Registration Requirements**

Registration requirements for each band pair are found by reading down the appropriate column and across the appropriate row.	<b>Standard Bands 1, 2, 3, 4, 5, 6, 7, and 8</b>	<b>Cirrus Band 9 and Thermal Bands 10 and 11</b>
<b>Standard Bands 1, 2, 3, 4, 5, 6, 7, and 8</b>	4.5 meters (required) <i>3 meters (goal)</i>	18 meters (required) <i>12 meters (goal)</i>
<b>Cirrus Band 9 and Thermal Bands 10 and 11</b>	18 meters (required) <i>12 meters (goal)</i>	18 meters (required) <i>12 meters (goal)</i>

### 9.6.3 Registration and Geodetic Accuracy

The requirements of Sections 7.2 through 7.5 shall apply to the optional reflective bands.

## Appendix: LTAP Acquisition Priority Algorithm

The Landsat-7 Long Term Acquisition Plan (LTAP) automates the selection of Landsat scenes to periodically refresh a global archive of sunlit, substantially cloud-free land images. By applying a set of algorithms on a daily basis, the LTAP is designed to ensure optimal collection of Landsat-7 ETM+ imagery for scientific applications, while minimizing the effects of cloud-cover and system constraints. Further background information on the Landsat-7 LTAP may be found within 427-HDBK-00005, LDCM Functional Description. This Appendix details the algorithm used to calculate acquisition priority scores referred to in Section 3.1.1.2.

The calculation of overall request priorities in the LTAP begins with the “base priority” of a particular scene. The base priority is a function of location (path-row) and date (acquisition window), but is normally set to 50 for scenes listed as “acquire once” or “acquire always” for a particular acquisition window. Thus, base priorities include both routine NDVI-derived acquisitions as well as niche science acquisitions.

The overall acquisition priority score ( $P_r$ ) for a scene is defined as:

$$P_r = P_b * ([1 + CC_{boost} * (CC_{nominal} - CC_{predict}) / 100] * MO_{current}) \quad (1)$$

Where:

$P_b$  is the base priority of scene (usually 50);

$CC_{boost}$  is the cloud cover priority boost constant, set to 3.0;

$CC_{predict}$  is the predicted cloud cover of the current scene from the forecast, ranging from 0-100;

$CC_{nominal}$  is the average seasonal cloud cover for this scene from the ISCCP data, ranging from 0-100;

$MO_{current}$  is the missed opportunity priority boost:

$$MO_{current} = MO_{boost} + [MO_{prior} * (1 - IQ_{max})] \quad (2)$$

Where:

$MO_{boost}$  is the missed opportunity priority boost constant, set to 1.0.

$MO_{prior}$  is the value of  $MO_{current}$  from the previous 16-day cycle if (i) the path row was scheduled as “acquire once” or “acquire always” during a different acquisition window and (ii) no successful acquisition occurred. If the request is new (i.e. there was no request for this path-row in the previous 16-day cycle as part of another acquisition window), then  $MO_{prior}$  is set to 3.0.

$IQ_{max}$  is the image quality of the best (clearest) acquired image of the current location during the lifetime of the current scene request (acquisition window). If no image has

been acquired for the current request then  $IQ_{\max} = 0$ .  $IQ_{\max}$  ranges from 0 to 1.0 according to:

$$IQ_{\max} = 1 - [(CCA_{\text{best}} - T_{\text{success}}) / (T_{\text{fail}} - T_{\text{success}})]$$

**(3)**

Where:

$CCA_{\text{best}}$  ranges from 0 to 100% and is (a) for “acquire once” cases, the lowest actual cloud-cover score of all images acquired during the current request period; or (b) for “acquire always” cases, the actual cloud-cover score of the most recently acquired image during the current request period.

$T_{\text{success}}$  is a constant defining the actual cloud-cover score below which an image is considered “cloud-free”, currently set to 10%;

$T_{\text{fail}}$  is a constant defining the actual cloud-cover score above which an image is considered to cloudy to be useful, currently set to 60%.

Note also that for “acquire once” cases at latitudes above/below 59 degrees north/south,  $CCA_{\text{best}}$  is actually the best cloud-cover score that can be mosaicked from images along adjacent paths.